REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*

2. REPORT TYPE
Technical Papers

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
2306

5e. TASK NUMBER
M1B3

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Leilani Richardson
a. REPORT	b. ABSTRACT	c. THIS PAGE	A		19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified			(661) 275-5015

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

6 separate items are enclosed

20050119 057

230 6m1B3

MEMORANDUM FOR PR (Contractor/In-House Publication)

FROM: PROI (TI) (STINFO) 26 Jun 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-AB-2000-141**
P. Wapner (ERC); W. Hoffman, "Micro-Hydraulics Employing Non-Wetting Fluids" (Abstract)

Fall Meeting of Electrochemical Society **(Statement A)**
(Phoenix, AZ, 22 Oct 2000) **(Submission Deadline: 07 Jul 2000)**

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.
Comments:____________________

Signature ____________________ Date __________

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.
Comments: ____________________

Signature ____________________ Date __________

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b.) appropriateness of distribution statement, c.) military/national critical technology, d.) economic sensitivity, e.) parallel review completed if required, and f.) format and completion of meeting clearance form if required
Comments:____________________

Signature ____________________ Date __________

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/ national critical technology, and f.) data rights and patentability
Comments:____________________

APPROVED/APPROVED AS AMENDED/DISAPPROVED

____
PHILIP A. KESSEL Date
Technical Advisor
Propulsion Science and Advanced Concepts Division

20021119 092

DISTRIBUTION A. Approved for public release; distribution unlimited.

Micro-Hydraulics Employing Non-Wetting Fluids

Hydraulic actuation is a mature technology that is widely used in a variety of applications in the macroscopic world. Its use in miniaturized devices, such as microelectromechanical systems (MEMS), however, is just beginning to be exploited. This lag in development of micro-hydraulics results from the fact that it is not easy to construct miniaturized analogs of macroscopic hydraulic system using traditional MEMS fabrication techniques, such as photolithography. Tight-clearance pistons that do not allow bypass flow are difficult to fabricate in micro-devices. Fortunately, the very fact that MEMS devices are so tiny enables a very different kind of hydraulic technology to be utilized. It is based on surface-related phenomena associated with flows of non-wetting fluids in micro-channels.

The utilization of pressurized incompressible fluids to achieve positive displacements of mechanical devices is a straightforward concept. Piston motion within a hydraulic system will take place providing force applied to the piston by an incompressible fluid is greater than forces opposing piston displacement, and no leaking or fluid bypass occurs. Also, no significant voids can exist within the system. Clearly, the first condition must be satisfied or motion can't take place. The second condition insures reproducible pressurization and fluid retention, while the third condition guarantees immediate transmittal of pressure in the incompressible fluid to the piston as well as other system surfaces. In macroscopic hydraulic systems, the use of good system design insures that the first and second conditions are fulfilled. The third condition is addressed in two ways. First of all, air bubbles are excluded from the system by precise filling techniques. Second, a hydraulic fluid is selected which wets system surfaces. This is done for a number of reasons. The primary reason being that if the hydraulic fluid does not wet system surfaces, tiny gaps and crevices will remain empty until sufficient pressure is created within the hydraulic fluid to generate the small-radius convex surfaces needed to fill them. These gaps and crevices would therefore behave like air bubbles resulting in reduced system performance. They would also greatly lessen the ability of hydraulic fluids to lubricate moving parts and prevent corrosion of the system. Non-wetting fluids are therefore not well-suited for use in macroscopic hydraulic systems.

In microscopic hydraulic systems, the reasons for choosing a wetting versus a non-wetting hydraulic fluid are not as straightforward. That is because as the dimensions of a hydraulic system decrease to the capillary sizes associated with MEMS devices, pressure within a non-wetting fluid gradually becomes elevated and can even surpass any externally applied pressure, such as that generated by a pump. Non-wetting fluids, by definition, do not enter into capillaries without pressure being applied. Once a column of such fluid has been forced into a capillary, however, this insertion pressure becomes an integral component of the parameters defining the nature or state of the non-wetting fluid while it is contained within the capillary. The total pressure, P_t, existing within the column then becomes the sum of the insertion pressure, P_i, and any externally applied

pressure, P_{ex}. Therefore, in micro-hydraulic systems operating with non-wetting fluids, three different pressures must be taken into account. No corresponding situation exists in macroscopic hydraulic systems using either wetting or non-wetting fluids, or in micro-hydraulic systems employing wetting fluids.

When the radius of a hydraulic cylinder is made smaller than 100 microns, the insertion pressure needed to force a non-wetting fluid such as mercury into such a cylinder becomes greater than 1 psi. Thus, at these dimensions, the pressure needed to create a non-wetting column of fluid is roughly the same order-of-magnitude as fluid pressures actually generated within such MEMS systems. KTH Instrumentation Laboratories in Sweden, for example, has constructed a valve-less diffuser micropump capable of a maximum pressure of 74 kPa (10.7 psi). If the radius becomes even smaller, the pressure needed to fill the system can become much larger than the externally applied pressure. This does not mean that the micro-hydraulic system cannot be fabricated. It simply means that some initial insertion pressure has to be employed to form the column of non-wetting fluid. Any external pressure applied after that point is added to the insertion pressure resulting in the total pressure for the system. Only the pressure applied externally, however, will be able to perform any external work as long as capillary dimensions in the micro-hydraulic system remain constant. If capillary dimensions vary, the potential energy contained within the non-wetting column of fluid will also vary, depending on actual geometry employed. This creates the possibility of performing more external work than is provided by any pressure applied externally to the non-wetting hydraulic fluid. Of course, the amount of external work that could be performed must be equal to or less than the potential energy created during insertion of the non-wetting column of fluid into the smaller capillary.